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ABSTRACT

This investigation was designed to test the hypothesis that the nature of the concept learned by a student is a function of the mode of instruction. Written materials were prepared to teach the concept "mib" to students in a remedial chemistry course. One set of materials presented the concept through a programmed text format consisting of 26 frames which presented the student with a figure and asked if the figure represented a mib; feedback for the frames enabled the student to determine the characteristics of the concept. Another set presented a verbal definition of a mib, a single example, and the instruction for the student to draw 26 mibs. A third set included a verbal definition, no example, and 26 illustrations from which the student selected examples of mibs. Materials were randomly distributed to 150 students. Two days later, students were asked to identify mibs in 20 illustrations and write a definition of a mib. Results indicated that the students who were given a definition developed a different concept than those students who learned the concept through multiple discrimination in the programmed format, indicating that a variety of learning activities are needed for adequate learning of concepts. (Author/MH)

CONCEPT FORMATION AS A FUNCTION OF INSTRUCTIONAL PROCEDURE

or

What Results from Ineffective Teaching

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Introduction

Faced with the realization that instruction is not as effective as we would like, it is logical to inquire whether another approach will lead to greater understanding. This proposition is frequently put to empirical test; the same ideas are taught by different procedures and a test is given to determine which treatment results in greater understanding. Although simple and logically sound, the multitude of conflicting results from evaluative research pointedly reminds us that teaching is complex and that a multitude of uncontrolled or even unrecognized variables may invalidate research results. What in one study may prove to be the more effective instructional procedure proves less effective under a new set of undefined conditions. Furthermore, in some cases the problem may not be one of relative effectiveness of two instructional procedures but rather, differences in the concepts that are actually taught.

The study described in this paper grew out of a classroom exercise in which lessons were developed to contrast "discovery" teaching with a simple "expository" presentation. The result of this informal activity seemed to point to differences in the nature of the concept developed by the two lessons rather than a difference in the effectiveness of the lessons.

As one proceeds through this report it will become obvious that the concepts presented in the contrasting instructional materials differ in subtle but important ways. Although obvious from a post hoc analysis, these differences were obscured in the beginning. It would be instructive for the reader to proceed as the author did in preparing the instructional materials.

Appendix C presents the instructional materials originally used to illustrate a "discovery" lesson.* As seen upon examination, these materials

* This exercise was obtained by the author almost 15 years ago and the source has been lost over time. My apologies to the original author for failure to provide deserved acknowledgment.

lead the student to a concept of "mib" through a series of trials in which the student makes some judgment concerning a figure and is then told whether the figure is or is not an example of a mib. The reader is invited to take a few minutes now to go through the exercise and, at the conclusion, write the definition for "mib" which results. This was the procedure followed by the author. After checking the result with a number of others who went through the exercise, the definition which forms the basis for the other treatments in this study was written. Appendices A and B present the instructional alternatives to that found in Appendix C. Results from a number of trials conducted before and after the study reported here indicate that individuals who go through the exercise found in Appendix C almost invariably write definitions for a mib essentially the same as that given in Appendices A and B. Although careful analysis will reveal that they are <u>not</u> the same, it is important to note that intelligent, thoughtful individuals easily overlook these differences.

Design

This study was designed to confirm what had been suspected since the original experience of teaching the concept of a mib by different methods; that the nature of the concept learned differed under different treatments. That such was the case appeared almost certain from the outset since the prior logical analysis indicated that the definition was not synonymous with the concept developed in the mib exercise. However, confirmation of the result appeared to be in order since history has often shown an obvious truth to be false.

The study was conducted in a remedial college chemistry class. Many of the students had low verbal skills, low quantitative skills, or both. There were three treatments in the study. Treatment A consisted of the

verbal definition of a mib, a single example, and instructions to draw 26 mibs. (Appendix A) Treatment B consisted of the same verbal definition, no example, and a sheet of 26 illustrations with instructions to circle those figures which were mibs. (Appendix B) Treatment C was the original mib exercise consisting of 26 frames which presented the student with a figure and then asked him to decide if the figure represented a mib. Feedback for each frame provided information which would enable the student to discover the characteristics of a mib. (Appendix C)

Materials were randomly distributed to students on the first day of class and were collected when the students had completed the exercise. Time required for completion of the exercise was approximately 10 minutes. Two days later, a test consisting of 20 illustrations was administered. (Appendix D) Students were asked to identify those illustrations which were mibs. At the conclusion of this part of the test, students were asked to write a definition of a mib.

Completed exercises and tests were obtained for 45 students in Treatment A, 46 students in Treatment B, and 44 students in Treatment C. A few students failed to give a written definition of a mib. Consequently, some of the ANOVAS which follow are based on data for 42 students in each treatment group. In order to obtain equal cell sizes, students were randomly deleted from treatment groups.

Three hypotheses were tested in this study. The three hypothesis, the data pertaining to them, and a discussion of the results are presented as Parts I, II and III.

PART I

Results: The major hypothesis to be tested was that the concept developed by students in the three treatments would differ. It was assumed

that if students in the three treatment groups developed the same concept, there would be no difference in the proportion of students in the three treatment groups who judged a particular figure to be a mib. Student responses for each of the 20 figures on the test were tabulated and the proportion of "yes" responses was calculated. Each item on the 20 item test was treated separately and a chi square was computed to test the hypothesis that there was no difference in the proportion of students who indicated that a given figure was a mib. The null hypothesis was rejected if chi square exceeded the value corresponding to an alpha of 0.05. Since 20 independent tests were performed, at least two tests must be significant in order to conclude that the concept developed by the treatment groups differed.

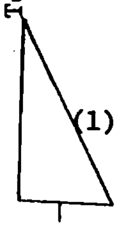
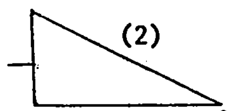
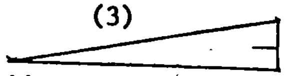
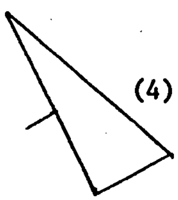
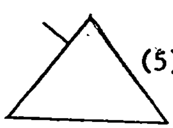
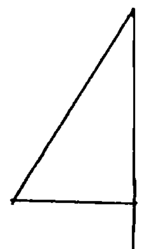
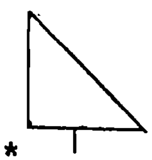
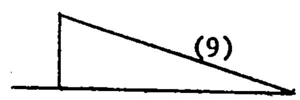
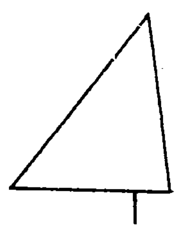
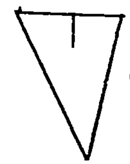
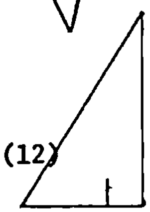
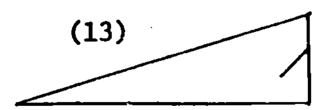
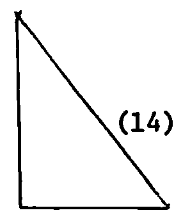
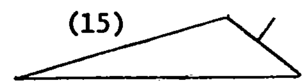
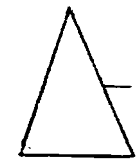
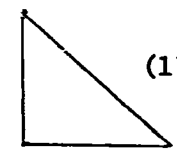
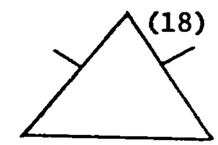
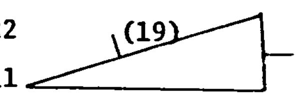
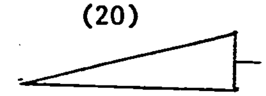
Table I shows each figure on the test, the proportion of students in each treatment group who identified that figure as a mib, and the value of chi square. Since significant differences were observed for 10 of the 20 figures, there seems to be little doubt that the concept of a mib that was developed by students in the three treatment groups was not identical. This result simply confirms what was believed to be true from the start.

Discussion: The above result shows that materials which were intended to teach the same concept did not. This result is undoubtedly due to poor teaching; materials that were intended to present the same concept simply did not. For the purposes of this paper, the importance of this result is related to its cause and the implications for more sophisticated studies designed to evaluate the relative effectiveness of contrasting instructional strategies.

Science educators are often frustrated in their attempts to obtain guidance concerning instructional practice because results from evaluative

Table I

Proportion of Students in Treatment Groups Judging Item to be a Mib

Test Item	Treatment	Proportion "yes"	χ^2
 (1)	A B C	.95 .89 .98	$X^2=3.25$
 (2)	A B C	.73 .56 .79	$X^2=6.07^*$
 (3)	A B C	.47 .56 .09	$X^2=23.8^{**}$
 (4)	A B C	.04 .17 .14	$X^2=3.85$
 (5)	A B C	.02 .15 .18	$X^2=6.18^*$
 (6)	A B C	.24 .30 .11	$X^2=4.93$
 (7)	A B C	.27 .43 .11	$X^2=11.7^{**}$
 (8)	A B C	.33 .56 .61	$X^2=8.05^*$
 (9)	A B C	.29 .43 .11	$X^2=11.5^{**}$
 (10)	A B C	.44 .52 .52	$X^2=0.726$
 (11)	A B C	.24 .24 .04	$X^2=7.82^*$
 (12)	A B C	.42 .72 .09	$X^2=36.4^{**}$
 (13)	A B C	.04 .24 .11	$X^2=7.68^*$
 (14)	A B C	.06 .13 .04	$X^2=2.37$
 (15)	A B C	.18 .19 .23	$X^2=0.349$
 (16)	A B C	.00 .00 .04	$X^2=4.20$
 (17)	A B C	.02 .09 .04	$X^2=1.99$
 (18)	A B C	.00 .06 .07	$X^2=3.14$
 (19)	A B C	.24 .22 .11	$X^2=2.72$
 (20)	A B C	.93 .78 .95	$X^2=8.08^*$

*Significant at .05 level

**Significant at .01 level

research are contradictory. For example, research which contrasts computer assisted instruction with "conventional" instruction sometimes suggests that CAI is more effective; at other times the conventional approach is found to be more effective. Reports of such studies seldom provide information which would enable the reader to assess the equivalence of the instructional materials and it is quite possible that, as in the case of this study, the contrasting instructional strategies actually lead to different concepts.

In order to clarify the point, let us focus on the differences in the concept presented under Treatment C of this study and the concept presented under Treatments A and B. To do this, it will help to focus on the attributes of a mib which are developed under the various treatments. Table II identifies the attributes presented under each treatment.

Table II. Attributes of Mib Presented to Treatment Groups

Attributes	Taught to Treatment Group		
A mib is	A	B	C
a right triangle	yes	yes	yes
with a separate segment	?	?	yes
which is perpendicular	yes	yes	yes
to the short leg	yes	yes	yes
extending outward	no	no	yes
from the center of the leg.	no	no	yes
The triangle may be scalene or isosoles.	?	?	yes

All three treatments should lead to a concept of a mib which is a right triangle with a segment perpendicular to the short leg. For Treatment C it appears that the segment is not one of the sides of the triangle. However, the definition given in Treatments A and B does not make this entirely clear.

In addition, Treatment C strongly suggests that the segment must extend outward from the triangle and be attached near the center of the short leg. The definition given under Treatments A and B makes no such stipulation.

Examination of Table I shows that the differences in response patterns for the three treatment groups occur for those figures in which a judgment is based on one of the attributes which is not made clear by the definition. For example figures 3, 11, and 12 all show a right triangle with a segment perpendicular to the short leg but the sement is <u>internal</u>. None of the learning materials contained such figures but the definition given to Groups A and B would include such figures as mibs; thus the difference in response. Similar comments can be made concerning figures 7 and 9. Here the segment is perpendicular and external but it is not at the center of the leg. Once again, no examples of this type were contained in any of the learning materials but would fall under the definition given in Treatments A and B.

It seems clear that the students in the three treatment groups did not develop the same concept because some of the learning materials were faulty. But it is impossible to say which materials were faulty. If the concept that we wish to develop would include examples such as those found in figures 3, 11, 12, 7, and 9 of the test, then the materials provided under Treatment C are faulty. They are faulty because the learning materials do not include examples of this type. If, on the other hand, the concept which one wishes to develop would exclude such examples, then the learning materials for Groups A and B are faulty because the definition does not specify two important attributes of a mib.

Note that the differences in the learning materials which led to acquisition of the different concepts were <u>unintentional</u> differences. Furthermore,

they represent differences that were not discovered until after the learning materials were used to teach and are examples of differences in instruction which might easily go undetected. One must ask how often materials used in evaluative research or normal instruction develop concepts through examples but fail to include a sufficient variety to identify all attributes of the concept or how often the definitions used are incomplete. In the absence of careful analysis, it is likely to happen all too frequently.

Some of the observed differences in the response patterns for the treatment groups are not accounted for by the "faculty" instruction described above. They do point to another instructional error which is no less common. It will be noted that the significant differences found in the responses for figures 2, 13, and 20 are due to anomolies in the responses for Group B. Fewer students in Group B considered figures 2 and 20 to be mibs even though the learning materials presented to each group would clearly define them as such. More students in Group B indicated that figure 13 was a mib even though the learning materials for all groups clearly indicate that such is not the case. These results imply that the learning materials for Group B were more ambiguous than materials presented to the other groups. This is probably true. Students in Group B were given 26 figures to mark but received no feedback to indicate whether their responses were correct. They were forced to rely <u>entirely</u> on the verbal definition which was provided. Students in Group C received feedback after each response that they made in the learning materials. Students in Group A did not receive feedback when they drew a mib but they were given an example of a mib which was evidently infuential in shaping the concept which they obtained. Although it is well established that feedback is an important component of instruction, it is all too easy to develop materials which are intended to be equivalent and still differ in this important characteristic.

Part II

Results: Earlier in this paper it was pointed out that the criterion test required the student to write a definition for a mib after checking the 20 figures presented on the test. Since Groups A and B were given a definition while Group C was not, it was hypothesized that students in Groups A and B would be better able to write a definition. This was the case. A large proportion (but certainly not all) of the students in Groups A and B gave a written definition which was equivalent to the one found in the learning materials. Far fewer of the students in Group C included all of the important attributes in their definition. The proportion of students in each group which included each attribute in their definition is shown in Table III.

Table III

Proportion of Students in Treatment Group Including Important Attributes in MIB Definition

Attributes	Treatment Group		
A mib is ...	A	B	C
a right triangle	.82	.89	.59
with a separate segment	.82	.80	.82
which is perpendicular	.75	.80	.52
to the short leg	.62	.74	.41
extending outward	.24	.06	.48
from the center of the leg.	.13	0	.20
The triangle is scalene.	.02	.02	.04

Before proceeding to the main point of this section, I call your attention to one interesting observation seen in Table III. It will be noted that 24% of the students in Group A specified that the perpendicular segment in a mib must extend outward and 13 percent indicated that it extended from the center

of the leg. The comparable percentages for students in Group B were 6% and 0% respectively even though the definition given to the two groups was the same. The only plausible explanation for this observed difference is the influence of the single illustration of a mib which was provided in Treatment A. That illustration showed the perpendicular segment extending outward from the center of the leg. Whether a single illustration would be this influential with students who have high verbal skills is open to question. That the single illustration did have this much influence on the students in this study seems worth some attention.

From Table III we see that the students in Groups A and B included the important attributes of a mib in their definition more frequently than did students in Group C. This is understandable. But the important question is whether these definitions really meant anything to the students. What we would like to know is whether the definitions that are written by the students are actually definitions that they use. In the case of this study, were the decisions made in marking the 20 figures on the test actually based on the definition that was written down or were they based on some different definition of the concept which was held intuitively but not verbalized? What is suggested here is that the student has two definitions, one which he verbalizes and another which he uses to make judgements concerning the 20 figures. Differences in the two definitions may be due to difficulties in verbalizing ideas or because the student uses criteria in judging the figures which he holds subconsciously. In either event, if the definition which the student verbalizes is identical to the definition which he actually applies when judging the figures, another individual should be able to apply the students' verbal definition and obtain the same results. Inconsistencies between the responses given by the student when marking the 20 figures on the test and responses which would be made under

a strict application of the definition written by the student may be interpreted as an indication that the student's verbalized definition is not the same as his working definition.

In order to check the consistency between the verbal definition and the working definition used by the students, each paper was evaluated by a group of judges consisting of the four authors. Before the papers were evaluated, the judges went through a period of training to establish an interjudge reliability above .90.

An example will help to show how an inconsistency was determined. Suppose that a student defined a mib as "a right triangle with a segment perpendicular to the short leg." Since figures 1, 2, and 3 are all right triangles with a segment perpendicular to the short leg, an error (inconsistency) would be recorded for each of these figures that the student did <u>not</u> mark as a mib. In like manner, an error would be recorded if the student <u>did</u> mark figure 4 as a mib since the segment in that figure is not attached to the short leg.

Because of the poor verbal skills of many students included in the study, it was expected that there would be a large number of inconsistencies. Furthermore, since it was assumed that many students in Groups A and B would parrot the definition given in the instructional materials without knowing what it meant, it was expected that there would be a greater number of inconsistencies for Groups A and B than for Group C.

The mean number of inconsistencies for Groups A, B and C were 4.76, 5.02, and 3.57 respectively. An ANOVA was performed to determine whether the means differed. The summary table for this analysis is presented as Table IV.

Table IV

ANOVA of Inconsistent Responses

Source	D.F.	S.S.	M.S.	F
Treatment	2	50.33	25.17	3.81*
Error	123	812.88	6.61	
Total	125	863.21		

* Significant at .05 level

The ANOVA indicates that the number of inconsistencies found for Group C is lower than the number of inconsistencies for Groups A and B and supports the hypothesis that there are greater similarities between the working definition and verbal definitions expressed by students in Group C than by students in Groups A and B. Although most teachers are well aware of the danger of accepting a student's definition of a concept as evidence that he understands it, this result emphasizes the futility of such commonly observed teaching practice.

Part III

Results: A third question of interest in this study was how well students learned the concept of a mib as presented in their respective learning materials. As pointed out in Part I, the concept presented to Groups A and B differed from the concept presented to Group C. Specifically, as the concept was presented to Group C, it must be infered that a figure is a mib only if the perpendicular segment is located near the center of the short leg of the right triangle and extends outward from the triangle. The definition presented to Groups A and B does not require either of these conditions. This presents a problem when evaluating the data to determine which treatment group made the greater number of errors in evaluating the figures. Since the concepts that were presented differ, the criteria for correct responses must differ as well. For example,

figure 3 <u>should</u> be considered to be a mib by students in Groups A and B since that figure meets all of the conditions stated in the definition. However, it should <u>not</u> be considered to be a mib by students in Group C since all examples in the instructional materials show an <u>external</u> segment. Figures 14 and 17 present an additional problem. One may argue that any right triangle fits the definition for a mib as presented to Groups A and B but the very mention of a segment in the definition implies that it must be a segment other than these forming the sides of the triangle. Furthermore, the responses given by the students and reported in Table I clearly show that students in all three treatment groups rejected these figures as examples of mibs. For this reason, in evaluating responses as correct or incorrect, figures 14 and 17 were considered not to be examples of mibs.

Papers for all three groups were evaluated to determine the number of incorrect responses. In grading the papers for Groups A and B, figures 1, 2, 3, 6, 7, 8, 9, 12, and 20 were judged to be examples of mibs as defined in the learning materials. In grading the papers for Group C, figures 1, 2, 8, and 20 were judged to be examples of mibs.

The fact that different criteria for grading were used in judging the papers for the three treatment groups raises serious questions concerning the validity of the results. However, the analysis was performed in spite of this limitation because there are implications that seem important to this author.

The mean number of errors made by Groups A, B and C were 5.52, 5.48, and 2.86 respectively. A one-way ANOVA yields an F of 14.8 which is significant beyond the .01 level. (Table V)

Table V

ANOVA of Incorrect Responses

Source	D.F.	S.S.	M.S.	F
Treatment	2	195.62	97.81	14.8**
Error	123	812.09	6.60	
Total	125	1007.71		

** Significant at .01 level

Discussion: One is tempted to conclude from this result that students learn better from a number of examples than from a definition. Although this may be true -- particularly for students with low verbal skills such as those used as subjects in this study -- such a conclusion is not warranted from these data. Had the definition given to Groups A and B been better formulated; i.e., had it stipulated that the segment must be external and near the center of the short leg and could include isosoles triangles so that the definition was entirely consistent with the illustrations presented to Group C, it is possible that the number of errors made by the three groups would have been the same.

What the above data do seem to indicate is that the learning materials for Group C were more effective in developing the concept presented in their materials than was the definition which was presented to Groups A and B. The explanation for this difference is not clear from the data but two considerations appear to be worth further consideration. First, it is quite likely that the technical language which was used in the definition was not understood by the students. Informal discussion with several students led the author to conclude that some students did not really know what was meant by such words as "right triangle", "perpendicular", "segment", and "leg". Clearly, words are ineffective in teaching if those words have no meaning. Second, students

in Group A had a single example of a mib. That example showed a figure with the perpendicular segment outside of the triangle and at the center of the short leg. Although the definition does not require that this be the case, the single example may provide a cue which is sufficiently potent to override the information contained in the verbal definition. Although Group B did not have an example which was specified as a mib, they did receive 26 illustrations, some of which were examples. None of these 26 illustrations showed an internal segment or one that was not located near the center of a side of the triangle. Once again, even though the definition does not specify these conditions, the illustrations seem to imply that these conditions are important. Examination of Table I seems to support the hypothesis that the illustrations had a disconcerting influence. Although substantially more students in Groups A and B than in Group C considered figures 3 and 12 to be mibs (as they are according to the definition), almost half of these students indicated that they were <u>not</u> mibs.

It would appear that more errors in identification of figures as mibs were made by students in Groups A and B because the information in the definition was not sufficient to unambiguously define the concept and because data derived from the illustrations was not entirely consistent with the definition. In other words, the results suggest that the instructional materials contain serious flaws that could result in the differences in "effectiveness" shown in this part of the study. Such flaws may be subtle or be incorporated inadvertantly but still lead to incorrect conclusions concerning the relative effectiveness of contrasting instruction strategies.

SUMMARY

The subtitle of this paper is "What results from ineffective teaching" and its purpose is to focus attention on the fact that ineffective instructional materials used as a part of evaluative research may lead inadvertantly to erroneous conclusions concerning the relative effectiveness of contrasting instructional methods. Perhaps no foolproof procedure exists to insure that two sets of instructional materials lead to the same understanding. However, work that has been done on the teaching of concepts does provide guidance which would preclude many of the instructional errors found in the materials used in this study.

It is normally assumed that a concept has been learned when the student is able to generalize the concept to all examples and when he is able to discriminate examples from non-examples. (Gilbert, 1962; Mechner, 1967; Englemen, 1969) In this study students were asked to demonstrate their ability to generalize the concept of a mib by identifying as mibs examples presented on the test which were different from the examples used in instruction. The student was asked to demonstrate his ability to discriminate by refusing to identify as a mib those examples on the test which lacked any attribute of a mib as presented in the instructional materials.

Failure to generalize a concept or to discriminate correctly may be attributed to inadequacies in instruction. Markle and Tiemann (1969; 1970) have argued that adequate instruction begins with an analysis of the concept to identify all important attributes. Such an analysis of the mib is illustrated in Table II and it is evident that the instructional materials used in this study were _not_ equivalent in pointing out these essential attributes. In addition to identifying the necessary attributes of a concept,

adequate instruction will also identify those irrelevant attributes which might interfere with proper discrimination. All of the materials used in this study were faulty in this regard because they failed to indicate whether the fact that the perpendicular segment was internal or external to the triangle was a relevant attribute. In addition, the materials used in Treatments A and B did not clearly indicate that size and spacial orientation are irrelevant attributes.

Once the relevant and irrelevant attributes of a concept have been identified, adequate instructional materials will provide examples which illustrate those attributes and aid the student in making discriminations Although a number of illustrations were used in the materials presented under Treatment C of this study, they were incomplete. There were no illustrations which enabled the student to determine whether "being external" or "being near the center" were necessary atributes of the segment on the mib. Materials presented under Treatments A and B were even more inadequate. Although a number of illustrations were presented under Treatment B, they were of little value because the student obtained no feedback when he marked them as mibs or non-mibs. Under Treatment A the student knew that the single example was a mib but since a single example may be consistent with many concepts (Englemann, 1969), it is not sufficient.

Verbal definitions are undoubtedly of value in teaching concepts; in this study, those who were given only a definition did not respond randomly to the items on the test. However, the definition alone will seldom constitute adequate instruction as illustrated by the performance of students in Treatment B of this study. It is also important to remember that the student's ability to state the definition does not provide evidence of understanding; e.g., note the inconsistencies between the stated definition and performance reported in Part II of this study. (Also see Markle and Tiemann, 1969).

This study shows that instructional materials which fail to identify the relevant and irrelevant attributes of a concept or which fail to include adequate examples and non-examples of the concept may lead to the development of different concepts. It is suggested that much of the evaluative research in science education which contrasts the effectiveness of various instructional strategies may lead to erroneous conclusions because of similar inadequacies in the instructional materials used in the contrasting methods of instruction. Those of us who engage in evaluative research have an obligation to demonstrate that, to the best of our ability, materials which are used have been analyzed and found to be equivalent in their presentation of the attributes of the concepts taught and in illustrating the important attributes of the concepts, even though the methods of presentation may differ.

The procedure outlined here represents a minimum level of responsibility; it does not insure that the instructional materials that are presented will, in fact, lead to the same concept while differing in effectiveness. For many science concepts, the kind of concept analysis described above (Markle and Tiemann, 1969; Romberg, et. al. 1971) is clearly difficult if not impossible. Words such as density, mass, atom, ideal gas, dynamic equilibrium, mole, acceleration, and inertia illustrate concepts which present problems, either in identification of attributes and non-attributes or in providing illustrative examples. Such "concepts by definition" (Gagné, 1966) present additional instructional problems and the procedure to be followed in order to insure that contrasting instructional materials are equally "adequate" is not entirely clear. Perhaps some kind of hierarchial analysis such as that proposed by Gagné for principle learning (1965) would provide the desired control.

In conclusion, this study illustrates that common inadequacies in instructional materials may lead to the acquisition of different concepts. It is pointed out that similar inadequacies in materials used for evaluative research may lead to erroneous conclusions concerning the relative effectiveness of contrasting methods of instruction. Researchers and classroom teachers have an obligation to engage in careful concept analysis in order to eliminate the common inadequacies of instructional materials used to teach science concepts.

Refereneces

1. Englemann, Siegfried. Conceptual Learning. San Raphael, California: Dimensions Publishing Co., 1969.

2. Gagné, Robert M. The Conditions of Learning. New York: Holt, Rinehart and Winston, 1965.

3. Gagné, Robert M. "The Learning of Principles" in Herbert Klausmeier and Chester Harris (eds). Analysis of Concept Learning. New York: Academic Press, 1966.

4. Gilbert, Thomas F. "Mathematics: The Technology of Education", Journal of Mathematics, Vol. 1, No. 1, 1962.

5. Markle, Susan M. and Tiemann, Philip W. Really Understanding Concepts. Chicago: Tiemann Associates, Inc., 1969.

6. Markle, Susan M. and Tiemann, Philip W. "'Behavioral'Analysis of Cognitive Content" Paper presented at the Conference on Teaching Chemistry to Underprepared Students, University of Illinois, Chicago Circle Campus, September 10-12, 1970.

7. Mechner, Francis. "Behavioral Analysis and Instructional Sequencing." In Large, P. (ed.) Programmed Instruction. 66th Yearbook of the National Society for the Study of Education, Part II. Chicago: University of Chicago Press, 1967.

8. Romberg, Thomas A., Steitz, Jean, and Frayer, Dorothy A. Selection and Analysis of Mathematics Concepts for Inclusion in Tests of Concept Attainment. Working Paper No. 55, Wisconsin Research and Development Center for Cognitive Learning, University of Wisconsin, Madison, Wisconsin, November 1971.

Appendix A

Name ______________________________

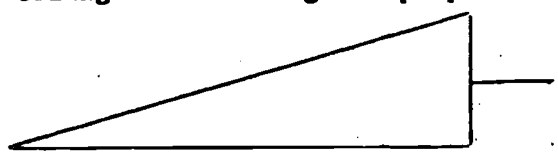
Section ______________

Lesson on the "Mib"

This short lesson is designed to illustrate different ways that students learn. The concept to be learned is that of a "mib".

A mib is a right triangle with a segment perpendicular to the short side.

Example:



This is a mib

In the space below or on the back of the sheet draw 26 mibs.

Name ________________________________

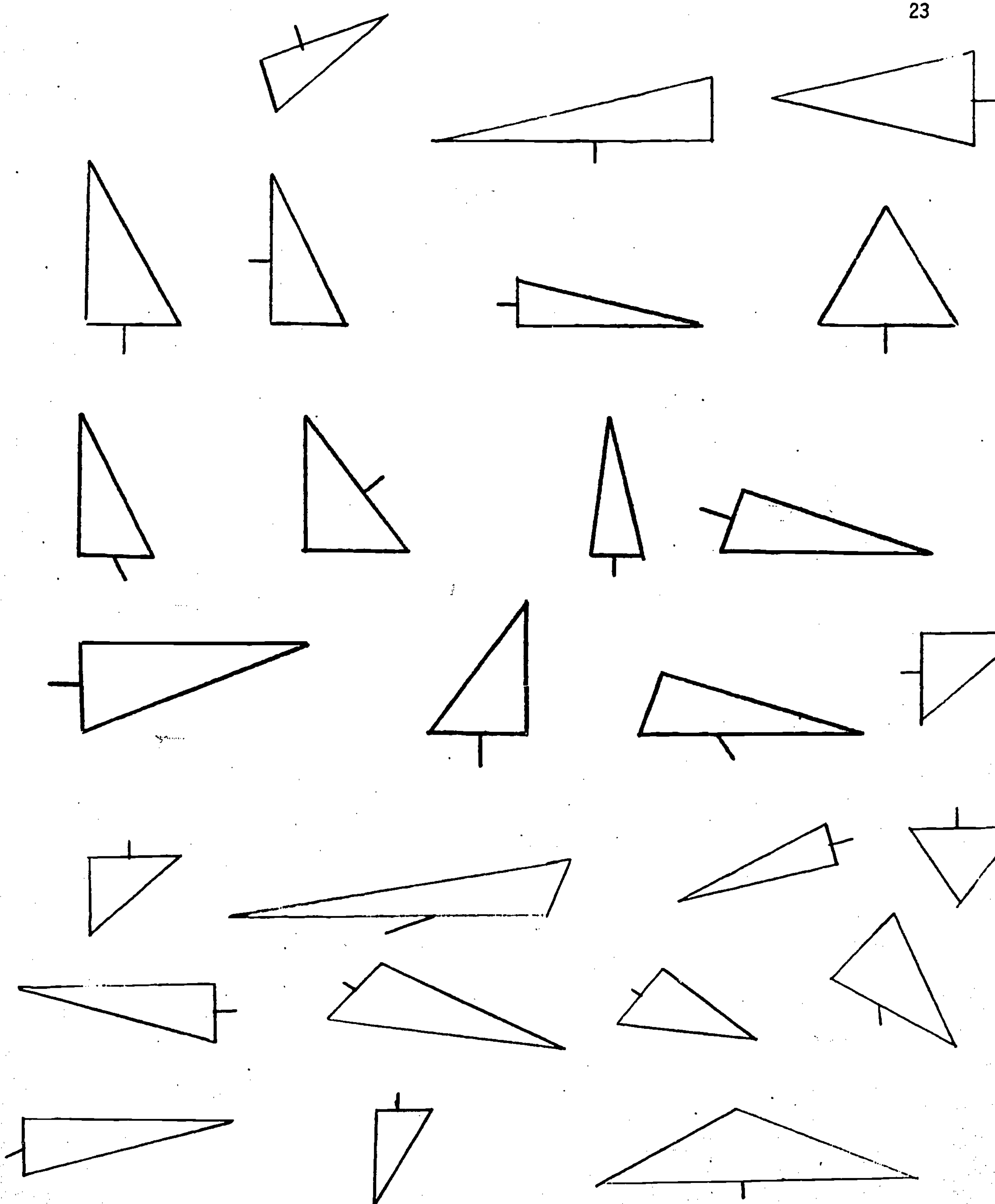
Section ______________

Lesson on the "Mib"

This short lesson is designed to illustrate different ways that students learn.

The concept to be learned is that of a "mib". A mib is a right triangle with a segment perpendicular to the shortest side.

On the following sheet of paper, identify the figures which are mibs by circling all mibs.



Appendix C

Lesson on the "Mib"

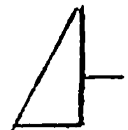
This task involves concept formation through successive trials. During each trial, place a ruler or piece of heavy paper along the dotted line below that trial. After you have made your response, move the ruler down to the next dotted line and proceed with the next trial.

In each trial you will look at a design and try to determine whether it is a "mib" or not. After a few trails you will begin to have hypotheses about what a mib is. Testing these through succeeding trials you will gradually discover what properties a mib has and does not have. In the end you will have an accurate concept of a mib.

When you have pencil and ruler or paper ready turn the page and begin.

Trial 1

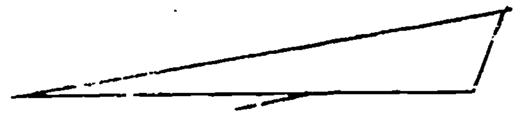
This is a mib.



Is this a mib? yes___ no___

Trial 2

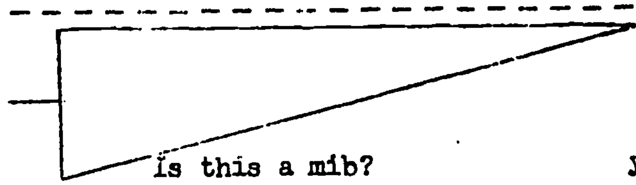
The second figure in trial 1 is not a mib.



Is this a mib? yes___ no___

Trial 3

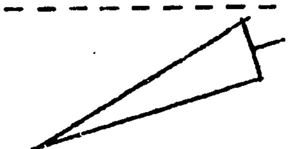
Trial 2 is not a mib.



Is this a mib? yes___ no___

Trial 4

Trial 3 is a mib



Is this a mib? yes___ no___

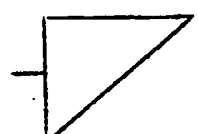
Trial 5

Trial 4 is a mib.

Is this a mib? yes___ no___

Trial 6

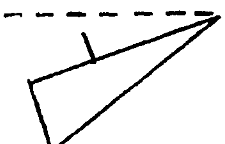
Trial 5 is not a mib.



Is this a mib? yes___ no___

Trial 7

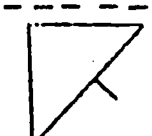
Trial 6 is a mib.



Is this a mib? yes___ no___

Trial 8

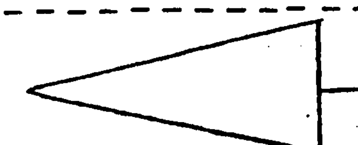
Trial 7 is not a mib.



Is this a mib? yes___ no___

Trial 9

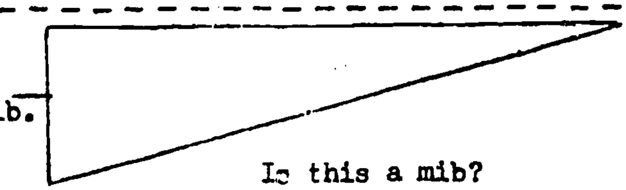
Trial 8 is not a mib.



Is this a mib? yes___ no___

Trial 10

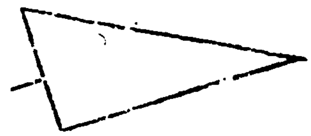
Trial 9 is not a mib.



Is this a mib? yes___ no___

Trial 11

Trial 10 is a mib.



Is this a mib? yes___ no___

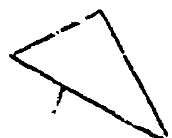
Trial 12

Trial 11 is a mib.

Is this a mib? yes___ no___

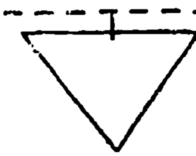
Trial 13

Trial 12 is a mib.



Is this a mib? yes___ no___

Trial 14

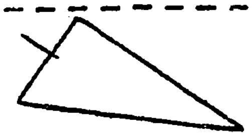


Trial 13 is not a mib.

Is this a mib? yes___ no___

Trial 15

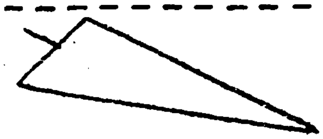
Trial 14 is not a mib.



Is this a mib? yes___ no___

Trial 16

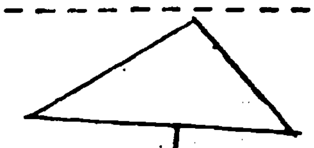
Trial 15 is a mib.



Is this a mib? yes___ no___

Trial 17

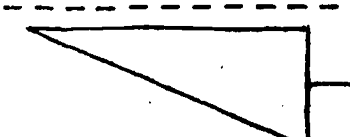
Trial 16 is not a mib.



Is this a mib? yes___ no___

Trial 18

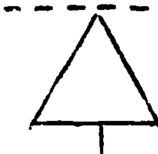
Trial 17 is not a mib.



Is this a mib? yes___ no___

Trial 19

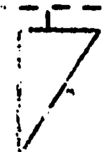
Trial 18 is a mib.



Is this a mib? yes___ no___

Trial 20

Trial 19 is not a mib.



Is this a mib? yes___ no___

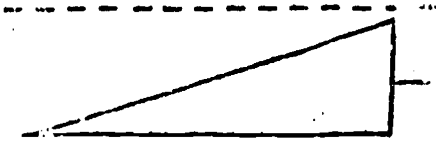
Trial 21

Trial 20 is a mib.

Is this a mib? yes___ no___

Trial 22

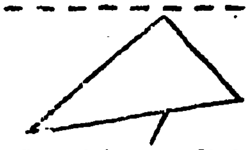
Trial 21 is not a mib.



Is this a mib? yes___ no___

Trial 23

Trial 22 is a mib.



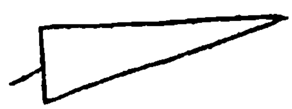
Is this a mib? yes___ no___

Trial 24

Trial 23 is not a mib.

Is this a mib? yes___ no___

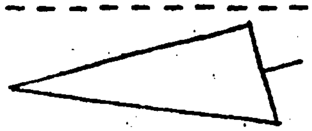
Trial 25



Trial 24 is not a mib.

Is this a mib? yes___ no___

Trial 26



Trial 25 is not a mib.

Is this a mib? yes___ no___

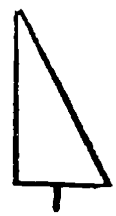
Trial 26 is a mib.

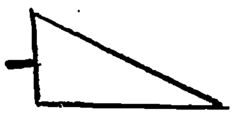
Quiz #1

Name:______________________________

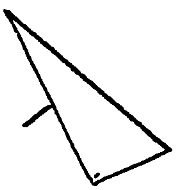
Section:____________________________

In the space provided beside each figure, write "yes" if the figure shown is a mib.

_____1.


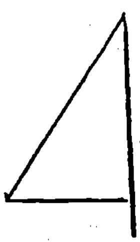
_____2.


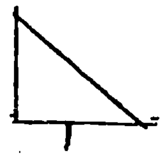
_____3.

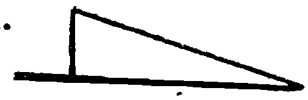

_____4.


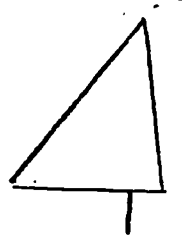
_____5.

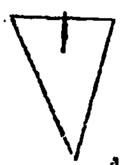

_____6.

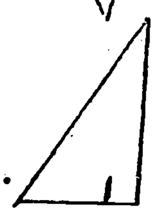

_____7.


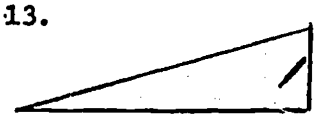
_____8.


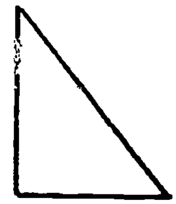
_____9.


_____10.


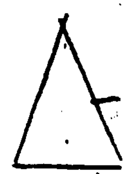
_____11.


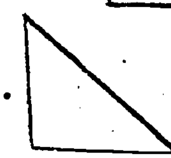
_____12.


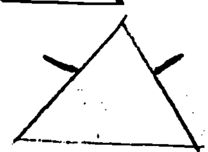
_____13.


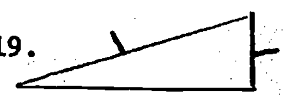
_____14.


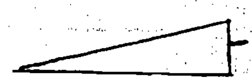
_____15.


_____16.


_____17.


_____18.


_____19.


_____20.


In the space below write a definition of a mib.

____

____